

ORIGINAL RESEARCH

THE NINE TEST SCREENING BATTERY - NORMATIVE VALUES ON A GROUP OF RECREATIONAL ATHLETES

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ABSTRACT

Background: A variety of risk factors predispose athletes to injury, such as impaired neuromuscular control, insufficient core stability, and muscular imbalances. The goal of assessing functional movement patterns is to detect imbalances and correct them with prevention strategies and thereby decrease injuries, and improve performance and quality of life.

Purpose: The purpose of this study was to generate normative values for the 'Nine Test Screening Battery' (9TSB) in a group of recreational athletes. A secondary aim was to study gender differences and differences between subjects with (more than six weeks before test occasion) and without previous injury (regardless of injury location). A third aim was to investigate the psychometric properties of the 9TSB.

Methods: Eighty healthy recreational athletes, (40 men and 40 women) aged 22-58, were included. The subjects were tested according to strict criteria during nine functional movement exercises that comprise the 9TSB; each graded using a ordinal scale of 0-3, at one occasion. The maximum possible score is 27 points.

Results: The median score for the whole group was 18 (Range 12 - 24). A normal distribution of the test scores, with no floor-ceiling effects was found. There was no significant gender difference ($p = 0.16$) or difference between the group that reported previous injuries (regardless of injury location) and the group that did not ($p = 0.65$). The internal consistency was 0.41 with Cronbach's alpha.

Conclusion: A normal distribution of test results with no floor-ceiling effect was found. History of previous injury (more than six weeks before testing) or gender did not affect the results. In order to determine and cut scores for what is considered optimal or dysfunctional movement patterns, further cohort studies are required.

Key words: Clinical test, functional movement, movement pattern, screening

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INTRODUCTION

Insufficient physical activity and sedentary lifestyles are a major public health problem.¹ Paradoxically, participation in recreational running events has been growing with more than 500,000 Swedes participating in recreational running events annually (and over a million people run without competing).² Participating in sporting activities is associated with injury risk among professional as well as recreational athletes.³ A range of often inter-related risk factors may predispose athletes to injury, such as previous injury,⁴ impaired neuromuscular control,⁴⁻⁶ insufficient core stability⁷⁻⁸ and muscular imbalances⁹⁻¹⁰. Prevention and rehabilitation of sport-related injuries is continuously evolving and it is an increasing interest among sport medicine professionals, researchers and athletes in prevention strategies focused on improving movement patterns.^{9,11-13}

Systematic assessment of functional movement patterns was first described in the 1990's when the Functional Movement Screen (FMS™) was developed.¹⁴⁻¹⁵ The FMS™ screens athletes for movement competency, and identifies pain during movements as well as musculoskeletal side to side imbalances, enabling correction and thereby reduced injury risk, improved performance and enhanced quality of life, according to the authors. Several research groups have investigated the inter-rater reliability of FMS™ with good results.¹¹⁻¹³ The FMS™ has been used as the basis for development of the 'nine test screening battery' (9TSB).¹⁶ The requirement for evaluating functional movements was spawned in the clinical setting due to the observed lack of mobility and stability among athletes and the concurrent lack of methodology for assessment. This too was the rationale for the development of the 9TSB, which consists of six of seven tests from the FMS™ with modified criteria. Modifications were conducted to make the criteria easier to follow for the testers, but also to make them more stringent. In addition to the FMS™ tests, one test (one-legged squat) was added from the United States Tennis Association (USTA) High-performance profile (HPP)¹⁷ and two tests (straight leg raise and seated rotation) were developed and standardized¹⁶ by the Swedish research team. The rationale for adding the three tests was that the FMS™ lacks screens for vertical rotation and more demanding strength tests. Pictures of the 9TSB tests are available in Appendix 1.

The 9TSB has previously been tested for inter- and intra rater reliability¹⁶ on a group of elite male soccer players with good results (ICC = 0.80). Low scores on the FMS™ has been found to be associated with increased risk of sustaining an injury in female collegiate athletes,¹⁸ professional football players¹⁹ and physically active students.⁸ In a study by Letafatkar et al²⁰ significant differences were found between pre-season functional movement screening scores in injured compared to non-injured individuals. Kiesel et al.²¹ found that those with asymmetries in FMS™ screening had higher risks of sustaining an injury during a professional season compare to those without asymmetries. Asymmetries are defined as a difference in performance on the bilateral tests (left-right extremity). Finally, Kiesel et al¹⁹ studied soccer players and found that functional movement screening (FMS™) followed by targeted interventions (improve range of motion, core stability, improve quality of movement) addressing the individuals dysfunction, could be used to change fundamental movement patterns evaluated with the same post intervention tests. In addition, they found a current paucity of data linking functional movement and athletes' injury susceptibility.

To date, only few studies²²⁻²⁵ have been published, describing normative values for the FMS™. No data on normative values have been published for the 9TSB, which makes it difficult to interpret raw data.²² The availability of reference values in healthy populations is vital when studying athletic cohorts at risk of injury.

The purpose of this study was to generate normative values for the 9TSB in a group of recreational athletes. A secondary aim was to study gender differences and differences between subjects with (more than six weeks before test occasion) and without previous injury (regardless of injury location). A third aim was to investigate the psychometric properties of the 9TSB.

METHODS

Subjects

Eighty healthy physically active subjects, (40 men and 40 women) between 22 and 58 years old, were invited to participate (Table 1). Subjects were primarily recruited by direct contact at a single recreational

Table 1. Background data, Mean (SD) or Median (Range) for all subjects (n = 80), men (n = 40) and women (n = 40).

	All subjects	Men	Women
Age, years (Mean \pm SD)	42.8 \pm 9.5	42.4 \pm 9.9	43.2 \pm 6.3
Weight, kg (Mean \pm SD)	69.7 \pm 12.1	79.1 \pm 8.5	60.2 \pm 6.4
Height, cm (Mean \pm SD)	174.7 \pm 9.8	181.9 \pm 6.9	167.4 \pm 6.3
Body Mass Index (Mean \pm SD)	22.8 \pm 2.3	23.9 \pm 2.1	21.5 \pm 1.6
Median training frequency days/week (range)	3 (2-4)	3 (2-4)	3 (2-4)
Training volume min/week (Mean \pm SD)	166.1 \pm 43.7	171 \pm 42.5	161.3 \pm 44.9

running event, secondly through e-mail contact via athletic clubs for recreational runners, and thirdly through personal contact with recreational athletes working at the Swedish Sports Confederation's Centre. The subjects were defined as recreational athletes by being physically active (endurance or strength training) two to four times per week, at least 30 minutes per session. Exclusion criteria were: recent musculoskeletal injury (within the previous six weeks) and/or sickness (within the previous one week). The reported physical activities performed by the subjects were running (n = 69), cycling (n = 35), strength training (n = 22), and group aerobic sessions (n = 13). Several athletes were active during the week in more than one sport activity.

All subjects were verbally informed of the purpose and procedure of the screening session, and written information was provided. Informed consent was obtained and prior to study commencement; ethical approval was obtained by the Regional Ethical Committee in Stockholm, Sweden.

Procedure

On the day of testing, each subject was informed verbally and in writing of the purpose and procedure of the study. The subjects were asked to complete a questionnaire providing background data. The data included is age, gender, weight, height, training frequency days/week, training volume (minutes of training/week), type of physical activity, previous injuries and/or significant illnesses and current medications.

During testing, each subject was barefoot, wearing a sport/tank top and shorts/tights. Before screening commenced, standardized verbal instructions were given and a picture of the starting and finishing posi-

tion of each test was provided. Three attempts of each test were performed and the score of the most correct movement, according to the criteria (Table 2), was recorded. The verbal instructions, the pictures and the allowance for making three tests, were agreed on as a way of familiarization process. If the technique was sub-optimal in the first trial, subjects were given corrective verbal instructions to optimize the performance in the subsequent two trials. If the test included bilateral testing, the left side was tested first. If the subject's scored differently on each side, the lowest score was registered as a final score for that test. One of the authors, a physical therapist (FF), with one year of experience of using the 9TSB, assessed all tests (n = 80) during a four-week period in 2011.

Nine test screening battery

The 9TSB was first described by Frohm et al¹⁶ and includes nine different tests: deep squat, one-legged squat, in-line lunge, active hip flexion, straight leg raise, push up, diagonal lift, seated rotation and functional shoulder mobility. The aim of the test is to analyse the quality of functional movement patterns during different tests. All nine tests have standardized starting positions with the quality of movement being graded 0-3. The highest score possible (3), indicates movement without asymmetries and compensatory movements. A score of 2 is recorded if the subject can perform the test but with small compensatory movements. A score of 1 is recorded if the subject cannot perform the test without major compensatory movements. If pain was present during a given test, a score of 0 is registered irrespective of performance.¹⁴⁻¹⁵ Thus, the highest possible aggregate score for the nine tests is 27 points (Table 2).

Table 2. Test criteria for the nine test screening battery

Tests	3 points (all criteria has to be fulfilled)	2 points	1 points
Deep squat test	<p>All criteria has to be fulfilled on a 0.02 m board:</p> <ul style="list-style-type: none"> • Straight line hip, knee and foot. • Parallel feet and heels kept on the board throughout the motion. • Femur below horizontal line. • Arms parallel to ears. • The pole is behind the toes. 	<p>Same criteria as for 3 points except the use of a 0.04 m board</p>	<p>One or more of the criteria have to be fulfilled (0.04 m):</p> <ul style="list-style-type: none"> • No straight line hip, knee and foot. • The feet are not parallel through the motion. • Femur is not below horizontal. • Arms are not parallel with the ears. • The pole is not behind the toes.
One-legged squat test	<ul style="list-style-type: none"> • Hip, knee and foot aligned. • Pelvis in horizontal line. • The upper body is vertical. 	<p>One or more of the following criteria:</p> <ul style="list-style-type: none"> • Hip, knee and foot aligned. • Pelvis is not in horizontal line. • The upper body is not vertical. 	<ul style="list-style-type: none"> • Hip, knee and foot is not aligned
In-line lunge test	<ul style="list-style-type: none"> • Pole contact with head and sacrum. • The upper elbow pointing 90° to the side. • No movement of upper body with a pole vertical. • Contact is kept between knuckle and columnna. • Both feet in line pointing straight forward • The anterior knee is straight over the anterior foot. Anterior heel is kept in the plank. • Rear foot touch the plank 	<p>One or more of the following criteria:</p> <ul style="list-style-type: none"> • No pole contact with head and sacrum. • The upper elbow not pointing 90° to the side. • Minor movement of upper body, pole is not vertical. • No contact between knuckle and columnna. • Feet is not pointing straight forward • The anterior knee is not in line over foot. 	<p>One or more of the following criteria:</p> <ul style="list-style-type: none"> • Loss of balance • Rear knee is not in contact with the plank • The anterior heel is not in contact with the plank
Active hip flexion test	<ul style="list-style-type: none"> • Lateral malleol passes the pole with both knees extended and neck in a neutral position . Pole at mid point between ASIS and mid patella. • Both knees extended and neck in a neutral position • The right knee is in contact with the board 	<p>The following criteria has to be fulfilled:</p> <ul style="list-style-type: none"> • Lateral malleol passes the pole between the measurement for 3p and mid patellae • Both knees extended and neck in neutral position • The right knee is in contact with the board 	<p>Lateral malleol does not pass the given criteria</p>
Straight leg raises test	<p>Ability to stabilize trunk with legs together, dorsi flexed feet with, heels touching the floor and back with retained position of the lumbar spine L4-L5. Neck in neutral position.</p>	<p>Ability to stabilize trunk with legs together to 30°.</p>	<p>No ability to stabilize trunk with 30° hip flexion</p>
Push up test	<ul style="list-style-type: none"> • The body is pushed up as a unit facing straight down through the whole motion. • Contact is kept between pole, back of the head as well as between the testers fingers and lumbar spine. 	<p>Both criteria have to be fulfilled:</p> <ul style="list-style-type: none"> • The body is pushed up as a unit facing straight down through the whole motion. • Contact is not kept between stick and back of the head or between the testers fingers and lumbar spine 	<p>The body is not pushed up as a unit</p>
Diagonal lift test	<ul style="list-style-type: none"> • Performs one diagonal lift with the right hand and the opposite foot and knee on a line • No visible rotation in the spine • Fully extended leg and arm in the horizontal plane • No abduction in either leg or arm • No winging of the scapula 	<p>All the following criteria have to be fulfilled:</p> <ul style="list-style-type: none"> • Performs one diagonal lift with hand and the opposite knee on each side of a line • No visible rotation in the spine • Fully extended leg and arm in the horizontal plane • No abduction in either leg or arm • No winging of the scapula 	<p>One or more of the following criteria:</p> <ul style="list-style-type: none"> • Performs one diagonal lift with hand and the opposite knee on each side of a line, with one or more of the following compensatory movement pattern • Visible rotation in the spine • Not fully extended leg and arm in the horizontal plane • Abduction in either leg or arm • Winging of the scapula
Seated rotation test	<p>Performs a slow rotation with the pole in touch with the chest until the poles touch each other</p>	<p>Performs a slow rotation with the pole in touch with the chest more then 45°. The poles are not touching each other</p>	<p>Performs a slow rotation with the pole in touch with the chest less than 45°.</p>
Functional shoulder mobility test	<p>Less than one hand length between the fists.</p>	<p>Less than one and a half length or more between the fists</p>	<p>One and a half hand length or more between the fists.</p>

STATISTICAL METHODS

80 subjects were recruited. According to Hatcher²⁶ the number of subjects should be five times larger than the number of variables (in this case a minimum of 5 times 9 = 45) when performing a factor analysis. Background data was analyzed with descriptive statistics, mean and standard deviation (SD) or median and range. The Mann-Whitney U test was used to analyze gender differences and differences between those with or without injury. The distribution of scores for all nine tests between men and women was analysed using the Chi-square test, with Alpha $p \leq 0.05$. To describe the variability among tests and evaluate the structure of the 9TSB a factor analysis was performed with varimax rotation and 0.50 levels for factor loading.²⁷ According to Fields²⁸ factor loadings closer to 1 are better, and a value of 0.5 is a suggested minimum to be counted as a loading factor. The number of factors was determined using a scree plot and an eigenvalues greater than 1.0 criterion. The quality of the analysis was assessed using the Kaiser-Meyer-Olkin (KMO) measure of sampling adequacy and Bartlett's test for sphericity. To describe the internal consistency among tests, the Cronbach's alpha was used. A cronbach's alpha above 0.5 is usually considered acceptable.²⁶ All statistical analyses were performed with the SPSS Statistics 20.

RESULTS

The median (range) total 9TSB score for the whole group was 18 (12 – 24), for men 19 (12 – 24) and for

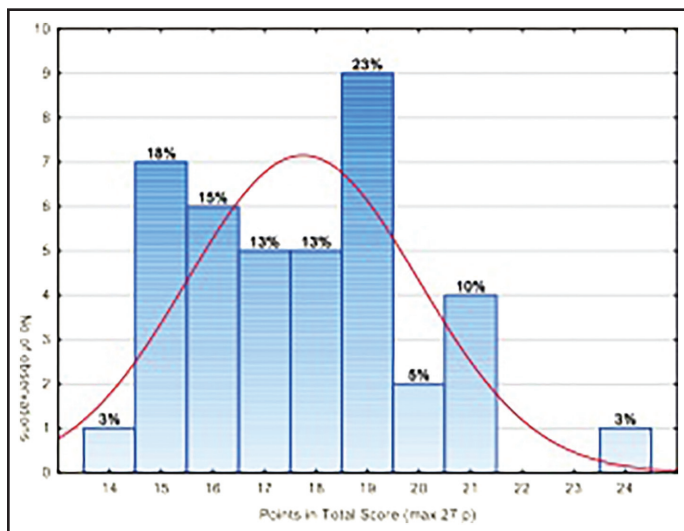


Figure 1. Distribution and percentage of scores for women ($n = 40$), maximum total score is 27 points

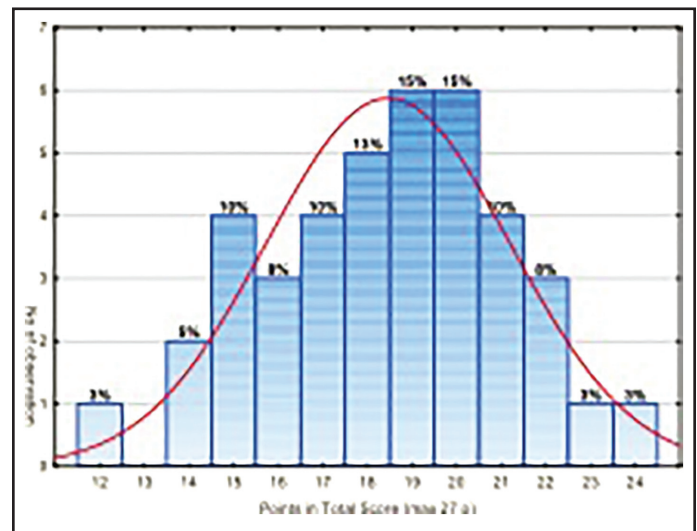


Figure 2. Distribution and percentage of scores for men ($n = 40$), maximum total score is 27 points.

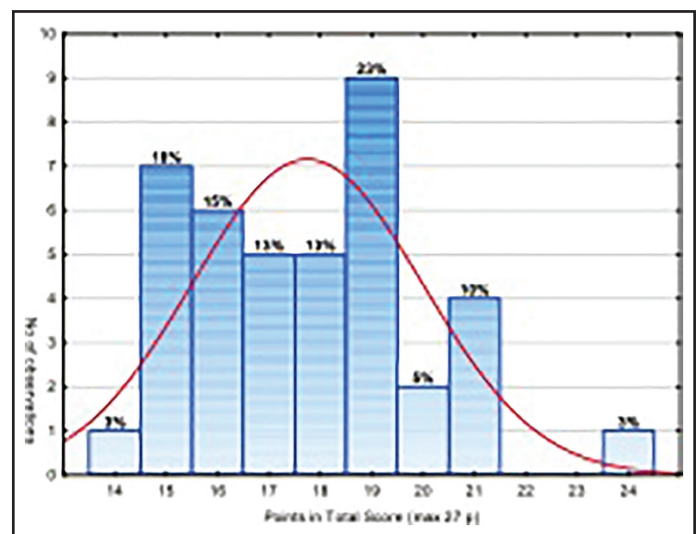


Figure 3. Distribution and percentage of scores for women ($n = 40$), maximum total score is 27 points.

women 18 (14 – 24). The group distributed essentially normally in scoring indicating that no floor or ceiling effects were seen. For distribution of scores, see Figure 1-3.

Gender differences

No significant gender difference in total score was demonstrated ($p = 0.16$). A median (range) total score of 19 (12 – 24) was found for men, and 18 (14 – 24) for women (Figures 2 and 3 demonstrate the distribution). In three of the tests: active hip flexion, straight leg raise and push up, a statistically significant difference ($p = 0.00$) was found between men

Table 3. Median (range) for men (n = 40) and women (n = 40) and p-values for gender differences for each included test (n = 9)				
	Men	Women	X ²	p
Deep squat test	2 (1-3)	2 (1-3)	5,08	0,08
One-legged squat test	2 (1-3)	2 (1-3)	0,47	0,80
In-line lunge test	2 (1-3)	2 (0-3)	6,05	0,11
Active hip flexion test	2 (1-3)	3 (2-3)	26,86	0,00
Straight leg raises test	2 (1-3)	2 (1-3)	11,02	0,00
Push up test	3 (0-3)	2 (0-3)	20,74	0,00
Diagonal lift test	2 (1-3)	2 (1-3)	2,22	0,33
Seated rotation test	2 (1-3)	2 (1-3)	1,92	0,38
Functional shoulder mobility test	2 (1-3)	3 (0-3)	4,2	0,25

Table 4. Factor analysis with varimax rotation for each included test (n = 9)				
	Factor 1	Factor 2	Factor 3	Factor 4
Deep squat test	0,39	0,52*	0,43	0,32
One-legged squat test	0,65	- 0,03	- 0,07	0,24
In-line lunge test	0,17	- 0,002	- 0,01	0,92*
Active hip flexion test	0,25	- 0,68*	0,29	- 0,19
Straight leg raises test	0,74*	0,32	- 0,08	- 0,1
Push up test	0,21	0,75*	- 0,04	- 0,2
Diagonal lift test	0,72*	- 0,05	0,04	0,07
Seated rotation test	- 0,08	- 0,02	0,81*	- 0,29
Functional shoulder mobility test	- 0,05	- 0,2	0,71*	0,3
* = Factor loadings above 0.5				

and women (Table 3). In the other six tests (Table 3), no gender difference was present. Men obtained higher scores on average in straight leg raise and the push up tests, while the women obtained higher scores in active hip flexion test. Women scored more maximum 3 scores than the men in two tests; active hip flexion (women 63%) and in functional shoulder mobility test (women 63%). In the rest of the tests, the men scored more maximum 3 scores than the women.

Previous injuries

No difference ($p = 0.65$) in median total score was determined between the group with a prior history of injury (> 6 weeks before test occasion), median (range) 18 (12 – 24) and the group who had no prior history of injury, 19 (14 – 24). The median (range) total score for the men that reported previous injuries was 18 (12 – 24) and 19 (14 – 22) for the men who did not ($p = 0.96$). The median (range) total score for the women that reported previous injuries was 18 (14 – 21) and 18 (15 – 24) for the women who did not ($p = 0.59$).

Factor analysis and internal consistency

The Kaiser-Meyer-Olkin measure of sampling adequacy for this study was marginally acceptable at 0.48, with factor loadings above 0.5 considered strong.²⁷ The factor analysis suggested that there were four different underlying factors linking performance in the 9TSB tests. The straight leg raise and diagonal lift tests were strongly related to one factor, with loadings of 0.74 and 0.72. The seated rotation and shoulder mobility tests were strongly related to another factor, with loadings of 0.81 and

0.71. The push up, active hip flexion, and deep squat test was also strongly related to a third factor, with loadings of 0.75, -0.68 and 0.52. The In-line lunge was strongly related to a fourth factor with a loading of 0.92 (Table 4). The internal consistency was 0.41.

DISCUSSION

The principal finding of this study was that there was no significant difference between men and women in total score on the 9TSB. However, there were significant differences between genders in three specific tests (active hip flexion, straight leg raise, and push up). The nine tests in the screening battery were related to four different factors according to the factor analysis. This indicates that the tests in the 9TSB can identify various dimensions of functional movements that are not necessarily related to one another. This was further confirmed with a Cronbach's alpha of 0.41 indicating that the nine tests reflect different aspects of an individual's movement pattern.

Even though no statistically significant difference was found in the total score between men and women, it is of importance to point out that there were three independent tests (active hip flexion test, straight leg raises test and push up test) with a statistically significant gender difference. A likely explanation could be a stronger upper body and increased trunk stability in men compared to women. Conversely, women scored higher in active hip flexion, which may be indicative of enhanced hamstring flexibility or hip joint mobility. The straight leg raise test challenges the stability of the trunk, to a larger extent compared to the active

hip flexion test that aims to investigate hip range of motion, which might reinforce this research group's theory. These reported gender differences are consistent with previous studies,²²⁻²³ that have examined the FMSTM in recreational and competitive athletes. These results might indicate that in the future the focus should not be on total score, but rather on single tests and asymmetries relevant individually to men and women.

To study potential correlations between the nine different tests, a factor analysis was undertaken, where four underlying factors among the nine tests was found. The straight leg raise and the diagonal lift tests were strongly related to one factor. The straight leg raise reflects one-dimensional dynamic trunk flexor strength¹⁶ and the diagonal lift reflects multi-plane trunk stability.¹⁴⁻¹⁵ It can therefore be postulated that these two exercises may be related to overall trunk stability. The seated rotation and shoulder mobility tests were strongly related to another factor. To hypothesise, that factor could be related to less mobility regarding rotational range of movement in the trunk and upper body. The push up, active hip flexion, and deep squat test was also strongly related to a third factor, again, to hypothesize, that could be overall strength and stability. The In-line lunge was strongly related to a fourth factor, indicating that this exercise alone is mirroring important aspects of physical functioning. It might be hypothesized that if two or more tests appear related to the same factor, at least one of these tests might be excluded. This would reduce the number of exercises in the battery and save time and resource. The KMO score from the factor analysis was marginally acceptable at 0.48, while the Cronbach's alpha was found to be (0.41) which is questionable. A low KMO score of 0.48, as found in the present study, can be indicative of a low sample size,²⁸ however, according to methods of Hatcher,²⁶ the number of subjects should have been sufficient. It could also indicate that all the nine different tests relate to different functional qualities and are thus required to be included in the screening battery. Factor analysis from Frohm et al¹⁶ demonstrated somewhat contradictory findings, which suggests that further studies are needed to evaluate whether tests within the existing 9TSB should be excluded or not.

There are several strengths of this study. This is the first study of its kind to provide normative values for the 9TSB in a group of recreational athletes. The 9TSB has been shown to be a standardized and reliable (ICC) tool¹⁶ that has been used for years in a clinical setting to assess functional movements and identify weak physical links during specific movements. This study provides some normative data of use for future studies, which should focus on specific age groups, types of athletes, and varied diagnoses or deficiencies.

Athlete screening followed by individual conditioning may be useful in reducing injury (acute and over-use) and hypothetically also have value in enhancing performance.⁸ The use of the 9TSB in this population of recreational middle-aged athletes showed no floor-ceiling effect, which indicates that the test battery was neither too easy nor too hard for this group to perform. A normal distribution of scores in women and men was found, with no clear age difference.

This study also has limitations. The sample size was relatively small when analyzing subgroups but large enough for factor analysis. A second factor worth considering is whether to start with the same side (left) or not in all bilateral tests. To randomize the starting limb might prevent learning effect and bias. With the result from this study, it was difficult to generalize the result to elite athletes. Another limitation is that the majority of the subjects performed the same type of exercise including non-contact sports and sagittal plane activities.

CONCLUSION

No difference in total score on the 9TSB was found between men and women, yet in three different tests (active hip flexion test, straight leg raises test and push up test) significant differences between men and women were found. Further, normally distributed 9TSB scores with no floor-ceiling effect were found, indicating that this test battery can be useful to assess functional movements in recreational athletes. These findings can serve as reference values for healthcare professionals when evaluating physically active individuals. Further cohort studies are required in order to determine cut scores or scores considered to represent optimal or dysfunctional movement.

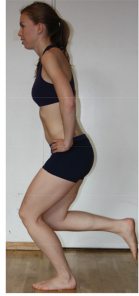
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Appendix



Deep squat test



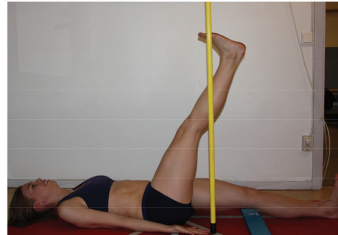
One-legged squat test



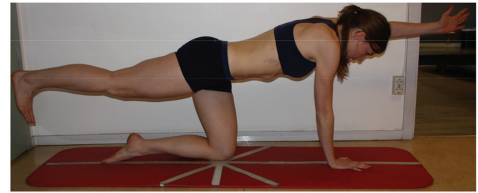
In-line lunge test



Straight leg raises test



Active hip flexion test



Diagonal lift test



Push-up test



Seated rotation test



Functional shoulder mobility test